THE MISSION RANGE, MONTANA

By W. M. DAVIS

Location and General Features. The Mission Range, one of the smaller members of the Rocky Mountains in western Montana, has the appearance, as seen from the west, of a gently tilted and moderately dissected fault block, gradually rising southward through its 70 miles of length, and believed to be composed of deformed rocks, mostly quartzites, of so uniform a resistance that no distinct expression of inner structure is recognized in outer form. It occupies the greater part of the distance between the Northern Pacific and the Great Northern Railways on the 114th meridian west of Greenwich. The steeper face of the range, probably representing the battered fault scarp, looks to the west. At the low northern end the moderately uneven crest emerges from beneath the glacial deposits which floor the broad intermont depression thereabouts at an altitude of 3,000 feet and rises slowly southward to a height of 9,800 feet near an abrupt southern descent, there gaining a maximum local relief of nearly 7,000 feet. The eastern side of the range is said to slope gently; the western face is steep. Thus the slowly rising crest and the long eastern slope suggest that the mountain block is an up-faulted fragment of a formerly worn-down mountain region, perhaps of low enough relief to be called a peneplane. Several other mountain masses in the same region exhibit a widespread accordance of summit altitude and thus support the conclusion that the forms of today are carved in the uplifted surface of a worn-down mountain region.

The mountain crest, slowly descending and dwindling away to the north, wedges off the branch intermont depression of the north-flowing Swan River on the east from the much larger and longer intermont depression of the south-flowing Flathead River and Lake on the west (map, Fig. 1). This depression is the southernmost part of the Rocky Mountain Trench, as it has been called by Daly.[1] In the district here concerned, the depression is limited on the east by the strong slope of the Galton and Swan Ranges of the Rocky Mountains and on the west by the more gentle ascent of the Flathead Mountains. On the gravel and silt plains of the depression, north of the lake, lies the flourishing agricultural town of Kalispell (altitude, 2,950 feet), reached by a southwestward, 15-mile spur from the main line of the Great Northern Railway. On the eastern shore

[1] R. A. Daly: The Nomenclature of the North American Cordillera Between the 47th and 53rd Parallels of Latitude, *Geogr. Journ.*, Vol. 27, 1906, pp. 586-606; see p. 596.

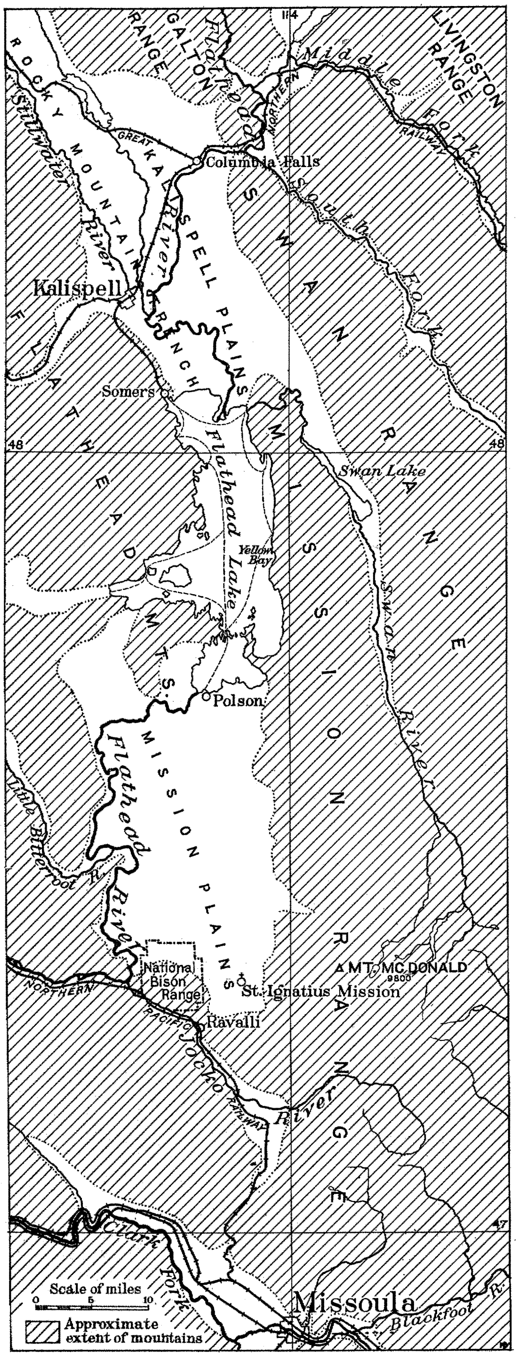

FIG. 1—Sketch-map of the Mission Range region, Montana, with the Flathead intermont depression. Scale, 1:1,100,000.

of Flathead Lake beneath the lower northern part of the Mission Range is the University of Montana Biological Station, the director of which, Professor Morton J. Elrod, has explored the district and published several essays upon it, in which the origin of the range by faulting and its glaciation are briefly mentioned.[2]

My own acquaintance with the Mission Range is brief. In connection with a Shaler Memorial Study in August, 1913, I took a rapid trip 80 miles southward from Kalispell and return and made many notes and sketches of the mountain forms as seen from the lake and plains on the west at distances of one to five or more miles. The diagrams here presented are redrawn from my hurried outlines and represent the range as if it were seen from an elevated point of view several miles to the west. They are roughly generalized figures, suggestive of the kinds of forms there exhibited, rather than sketches of actual details; they undoubtedly exaggerate certain features; they are bare of vegetation; their uncompromising black lines cannot portray the soft-

[2] The Beauties of the Mission Range, *Rocky Mountain Mag.*, 1901, pp. 623-631.

A Biological Reconnaissance in the Vicinity of Flathead Lake, *Bull. Univ. Montana: Biol. Series No. 3*, 1902, pp. 91-182.

The Physiography of the Flathead Lake Region, *ibid.*, No. 5, 1903, pp. 197-203.

ness of the graded slopes; the diagrams are indeed hardly more than caricatures of the picturesque reality; yet if allowance is made for their limitations they may serve to make the following text and the photographs more easily intelligible. The photographs come from the collection of the U. S. Geological Survey, to which my thanks are hereby rendered; some of them are by Dr. C. D. Walcott, others by Mr. R. W. Stone. Their accuracy is delightful, and the abundance of detail in certain views is extraordinary; but the relation of the parts that they so well represent to the whole of the range is nevertheless aided by the rough diagrams.

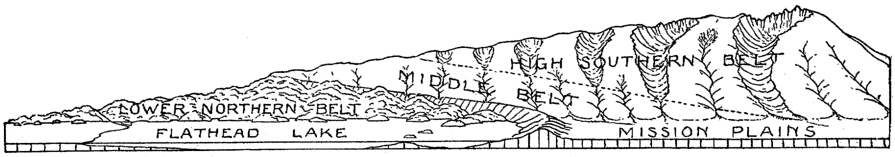

FIG. 2—The three belts of the Mission Range.

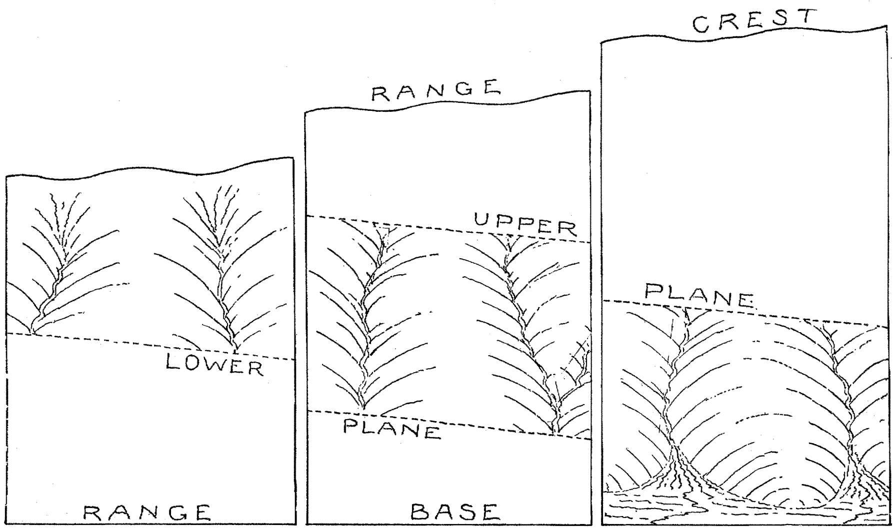

FIG. 3—The normal features of the middle belt.

The Three Belts of the Range. The present features of the Mission Range, as seen from the intermont depression on the west, may be divided, in so far as they are due to erosion since uplift, into three oblique belts, as in Figure 2, by two planes slanting gently to the south and about 1,000 feet apart. Through the middle of the range where the limiting planes overlap all three belts are represented.

The Middle Belt. In the middle belt, confined between the two planes, the mountain-side forms are all due to the normal erosional forces of weather and water. Owing to the overlap of the planes, a continuous descent cannot be made at any one point within this belt from mountain crest to mountain base; the overlap is indeed so great that portions of the belt must be taken, as in Figure 3, at three places in order to show a spur

summit and valley heads as on the left, the mid-descent of a spur and valleys as in the center, and a spur end and piedmont fans as on the right. The crest of the range here shows rounded, waste-covered summits; the slope is diversified by maturely graded, large-textured, full-bodied spurs between the wide-spaced, steep-pitching, apparently consequent valleys of small and rapid streams. The summits and a good part of the graded spurs are treeless. As is usual in forms of this kind the rarity of rock outcrops makes outline sketching difficult; there are not enough lines to express the forms. The concave forward reach of the tapering spurs as they blend into the piedmont plain is far beyond my power of black-line representation in a front view. The well-rounded forms of the spurs suggest that the inferred original fault-scarp of the supposed mountain block is completely destroyed by retrogressive erosion; and, if so, the upper parts of the streams should be regarded as obsequent extensions of the original consequents, inasmuch as they must now discharge to the westward a certain amount of rainfall captured from formerly longer east-flowing consequents. There is no trace of spur-end facets along the western mountain border, such as characterize the up-faulted and less dissected Wasatch Range in Utah; the valleys, instead of preserving their V cross-section to a simple base line, as in the Wasatch, open on fans that form re-entrant cusps between the advancing scallops of the spur ends. What relation exists between the rock structure and the scalloped base line I cannot say.

A characteristic feature of the maturely carved middle belt is the well-organized system of down-hill lines by which the descent of water and waste is made from any point on the slope to the mountain base. All the paths of descent first follow the down-hill element of a well-graded spur

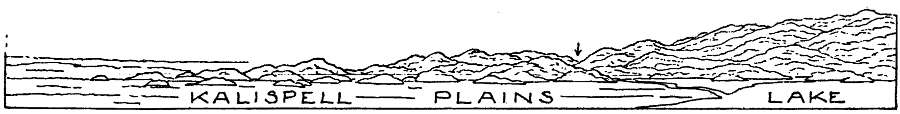

FIG. 4—Northern end of the range emerging from the plains.

side to a stream; then the down-valley element of a stream course to the piedmont plain. The spur-side elements are countless; contiguous elements are nearly parallel to one another, being but slightly convergent or divergent; their declivity changes so slowly and systematically as to insure a steady though very deliberate progress of the continuous waste cover, as it creeps and washes toward a stream. The stream lines are comparatively few, probably not more than eighty or one hundred in the three southern quarters of the range length where streams are normally developed. The rock waste, slowly fed from the spur sides into the streams, is rapidly washed down the channel to the mountain base; for, as well as I could see, the channels seem to be fairly well graded, though they doubtless still retain many little rocky rapids and bouldery pools; and their declivity appears to be such that the streams gain just the velocity that enables

them to do their work of transporting the waste received from the spur sides, with a very small addition supplied by corrasion of beds and banks. The only down-hill lines that do not join a stream are those that follow a spur axis, and these are the lines along which the ascent of the slope is most easily made: their declivity is greatest near mid-height but seldom over 30°, and is much less than that for some distance above the base and below the top.

The Low Northern Belt. In the lower northern belt the smoothly flowing, waste-covered forms of the middle belt are replaced by uneven forms of small texture—bare crags and knobs, cliffs and ledges, channels and hollows—due to recent and severe but immature scouring by a broad and overwhelming glacier of Canadian origin. Similarly immature crags and knobs occur in the glaciated areas of central France[3] and North Wales.[4] Tree growth on the craggy slopes here seen is more abundant than on the waste-covered spurs of the middle belt, and a good share of the surface is thus concealed; but the bare and uneven ledges are so plentifully visible that I felt no doubt of their extending under the tree cover as well. Outline sketching is, however, again difficult because the innumerable rock outcrops now provide details so abundant that there are too many lines to draw; needless to say that the knobs and cliffs shown in my diagrams are not minutely accurate copies of actual forms.

The northern half of this belt forms the northern quarter of the range and lies entirely beneath its limiting plane, as in Figures 4, 5, and 6; it has

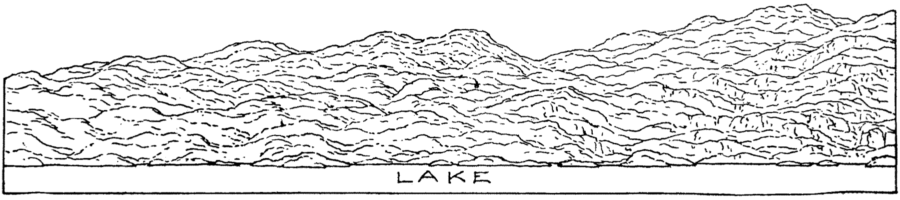

FIG. 5—The gradual rise of the scoured northern belt.

an arbitrarily uneven crest, the profile of which lies beneath the northward prolongation of the non-glaciated crest in the middle belt by one or several hundred feet, as if worn down by glacial scouring. The side slope of rubbed and roughened hills and hollows is a medley of unorganized forms; it has no sign of the well-arranged lines of continuous descent by which the middle belt is characterized and no indication of the delicate interdependence of parts that Gilbert long ago, in his classic report on the Henry Mountains, showed to be an essential characteristic of streams and surfaces that had been long enough exposed to the normal processes of subaërial erosion for the development of mature drainage systems: naturally not, for

[3] W. M. Davis: Glacial Erosion in France, Switzerland, and Norway, *Proc. Bost. Soc. Nat. Hist.*, Vol. 29, 1900, pp. 273-322; reference on p. 276.

[4] W. M. Davis: Glacial Erosion in North Wales, *Quart. Journ. Geol. Soc.*, Vol. 65, 1909, pp. 281-350; reference on p. 336.

the irregular slopes here seen are not the work of down-hill washing and creeping by water and weather, but of side-hill scouring and plucking by a huge glacier, moving almost horizontally southward and at so recent a date that small advance toward the development of normally carved forms and toward the establishment of well-organized drainage systems is yet to be seen. There appears, however, as far as I could make out by repeated examination with a field glass, to be some talus at the foot of cliffs and some smooth flooring of detritus gathered in the hollows and there may be small gorges cut in rock sills by the plunging streams. The lines here followed by falling, rolling, and creeping waste are short, irregularly disposed, and of rapidly changing declivity; they radiate in all directions from countless knobs and hillocks, they converge in all directions toward countless channels and hollows: the lines followed by leaping and lagging streams are frequently deflected almost parallel to the range front, in one direction or the other, as if following small troughs worn along the face of the mountain slope; the streams must therefore turn this way and that, they must alternately hurry and loiter, striving to wear down ledges that are too steep and to fill up sags that are too flat, the latter task probably being farther advanced than the former. Streams thus arranged form an elabo-

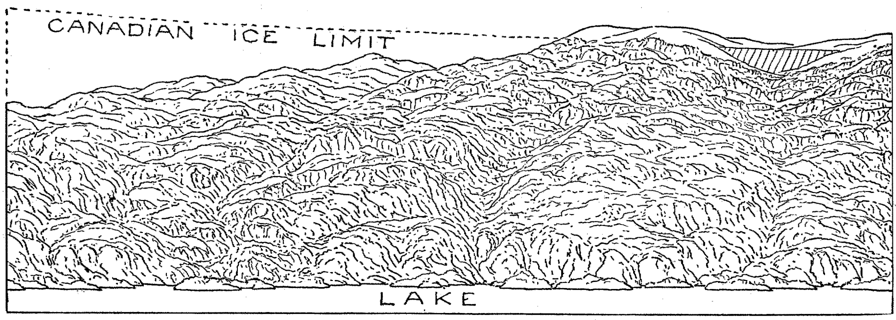

FIG. 6—The scoured northern belt overlapped by the middle belt.

rate branch work; Y-junctions are very frequent, the stems of the smaller upper y's forming the branches of the next lower and larger ones, over and over again. As a result no direct stream lines for the descent of water and waste from the range crest are seen here, and no continuous spur axes to guide paths of direct ascent from the range base. The branch-work stream system thus constituted stands in strong contrast to the single-line streams of the normally eroded middle belt; yet the branch-work streams as well as the single-line streams are consequent, in the sense of following courses offered to them when taking possession of the surfaces that they drain; their differences are chiefly due to difference in the nature of the surfaces offered to their action, and for the rest to differences in their stage of development; for the single-line streams are almost mature, while the branch-work streams are very young: but all this contrast is implied

in saying that the northern end of the range shows "uneven forms due to recent and severe but immature scouring by a broad and overwhelming glacier."

Northern End of the Range. If the range is followed farther north, as in Figure 4, its height decreases with a somewhat regular irregularity until the last visible knobs, deeply scoured and channeled and plucked, more or less detached from one another, rise hardly a hundred feet above the surrounding plain of out-washed glacial gravels and silts diversified by low morainic hills, which here occupies the broad intermont depression and presumably covers a farther northward extension of the range crest underground. Some of the knobs lie somewhat west of the line that farther south follows the mountain base, and this suggests that the strong fault by which the central and southern part of the range is thought to be limited, may here, near the least uplifted end of the mountain block, be represented by an up-warped or up-arched mass of which the western limb corresponds to the underground wing of the fault farther south. Low as the range is here, the rocks of the knobs are resistant and apparently of the same nature as those which form the lofty mountain crest to the south. Evidently, then, the northward diminution of range height cannot be due to degradation of a once much loftier mass in the present cycle of erosion, but rather to the northward decrease in the uplift of a previously worn-down mass. The range rises highest where the uplift, increasing southward along the edge of the supposed fault block, has its greatest value.

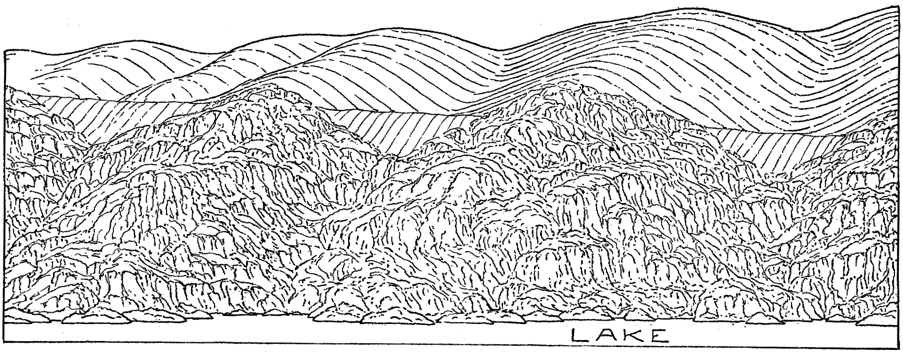

FIG. 7—Morainic embankments between normal summits and scoured slopes.

A curious feature of the trailing northern end of the range is its transection by the Swan River, which, instead of making a northward detour and avoiding all the rocky knobs, takes a short cut westward through them on its way from its own valley on the back-slope side of the Mission fault block to the larger Flathead valley on the fault-scarp side. This is presumably a persistent consequence of temporary constraint by the waning mass of the Canadian glacier; if so, search should be made in notches at higher levels in the trailing crest for transverse water-worn channels marking temporary

outlets of a proglacial lake in the upper Swan River valley; and it is quite possible that the highest channel of all may occur at the head of the valley westward around the southern end of the Mission Range or southward over the neighboring hills directly into the valley of Jocko River.

Truncated Spurs and Morainic Embankments. If we now turn southward to the second fourth of the range, where its crest rises above the limit of glaciation, as in Figure 6, the normally rounded summits and the normally hollowed valley heads of the middle belt make their appearance above the rugged slope of glacial erosion. The valleys are barred across by what I take to be morainic embankments (Figs. 7 and 8), which record the height of glacial action to a nicety; the spurs are imperfectly truncated in irregular cliffs and ledges, strongly scoured along the mountain side.

Below the gently slanting line defined by the moraines, the disorderly tumult of bare cliffs and ledges in the imperfectly truncated spur ends forms a striking contrast with the subdued orderliness of the waste-covered higher slopes; the subdued forms of large texture express a long and suc-

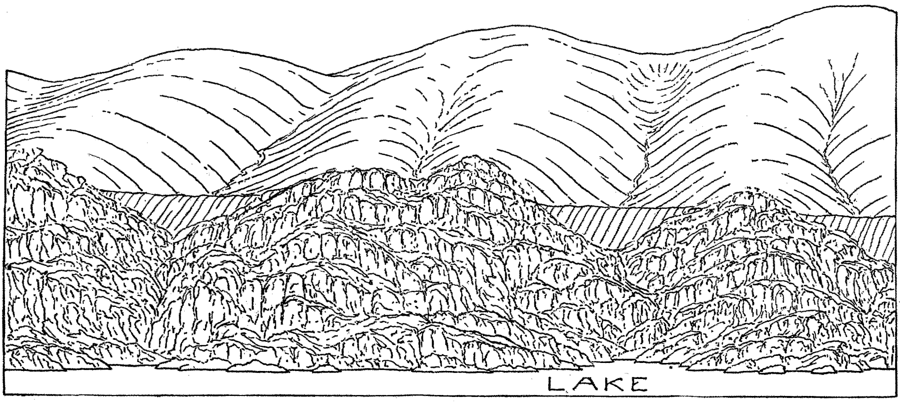

FIG. 8—Normal slopes above scoured slopes.

cessful continuity of degradational processes; the disorderly forms of small texture express a striving and unsuccessful discontinuity. Above, all the local variations of rock structure, such as are determined by the composition, thickness, and attitude of successive beds and by the number and inclination of joints, are practically without influence upon the form of the surface because local and individual influences are masked by the generalizing effect of the creeping cover of rock waste; below, the masses and planes of structural strength and weakness are strongly expressed in the bared rock faces and fissures of the many cliffs and benches.

The streams in this fourth of the range exhibit a haphazard habit in their plunging courses, for the valleys as well as the spurs are largely obliterated below the line of moraines. Cascades and pools must be frequent in watercourses that are consequent on the smaller forms of so rocky and rugged a mountain side; as far as I could see, little progress towards

establishing a graded profile has been accomplished. In the absence of pronounced spurs and valleys, the whole mountain side here descends like a battered wall and dips under the waters of Flathead Lake, of which the eastern shore line is comparatively simple when viewed as a whole but minutely irregular when viewed in detail. The western shore line is much more sinuous. There are, however, two eastern re-entrants of small size, Woods and Yellow Bays, roughly represented in Figures 7 and 8, which appear to occupy scoured hollows between spur remnants, but as to this I am uncertain; the buildings of the Biological Station of the University of Montana are beautifully situated on the north side of Yellow Bay, where a gravel delta, not shown in the diagram, now occupies part of the original re-entrant.

As one advances farther southward, some of the morainic embankments are trenched by the streams from the normal valleys behind them, as in

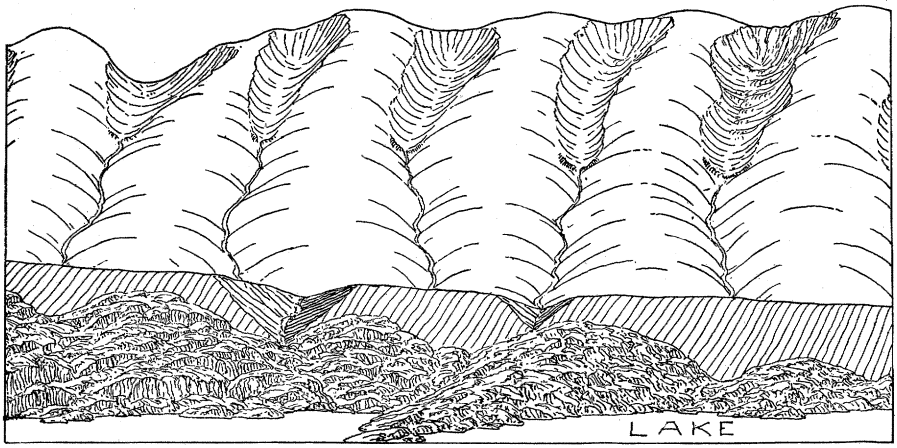

FIG. 9—Small cirques above a continuous moraine.

Figure 9, the spur ends are scoured to less and less height, and their truncation is less and less effective; one of the spurs advances in a low promontory and is continued across the lake by a string of small islands, one of which is shown in Figure 16. The ruggedness of its nearby rocks justifies the generalized details of the glaciated slopes in Figures 7, 8, and 9, although such details are not shown in the photographic view of the range from one of the rocky islands (Fig. 18). Farther on still, the embankments stand at less and less heights above the lake and at the same time become larger and longer, until they ride over the spurs and thus form a long unbroken ridge, which gradually departs from the base of the range, as in Figures 9 and 10. The morainic ridge in this part of its length is truly only about half as high as the 1,500-foot embankment that forms the northern side of the huge morainic amphitheater in which the ancient glacier that followed the valley of the Dora Baltea from the southern side of the Mt.

Blanc group ended on the plains of Italy at Ivrea; nevertheless it constitutes a formidable monument of glacial construction, which becomes especially conspicuous as it swings away from the mountains in the noble terminal moraine, dotted with boulders, that sweeps westward across the intermont depression with a relief of 400 or 500 feet—see Figure 2—and a breadth of one or two miles, separating Flathead Lake on its concave northern side from the Mission Plains, chiefly composed of earlier glacial deposits, on its convex southern side. The lake outlet follows a trench sharply cut across the moraine at the southwestern angle of the lake; the town of Polson lies on the morainic slope next east of the outlet, and gives its name to the moraine.

The truncation of mountain-side spurs by a passing glacier is of familiar occurrence in the valley troughs of formerly glaciated mountain ranges; it is less familiar as a feature of ranges that border broad intermont plains.

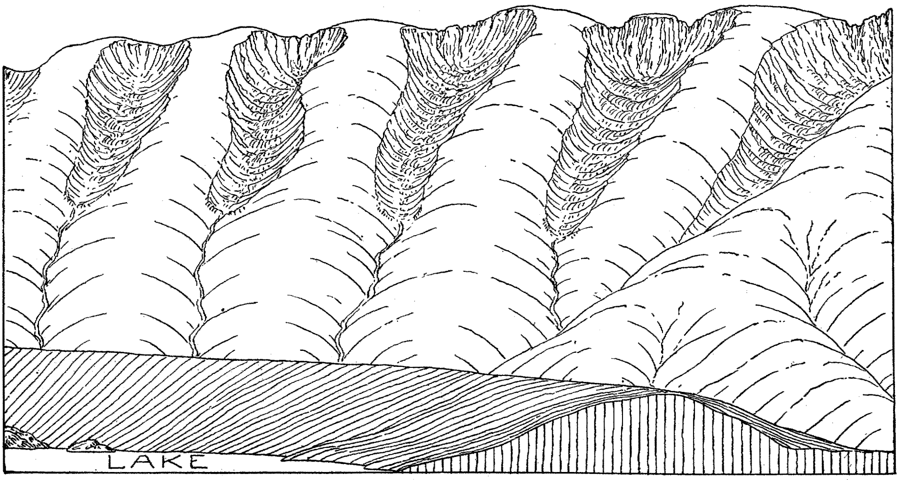

FIG. 10—Larger cirques: the moraine curves westward.

Yet another example of such truncation occurs not far away to the northeast, where the flanks of the Galton and Swan Ranges, the former far northward and the latter for some ten or fifteen miles south of the deep notch by which the Great Northern Railway enters the mountains from the broad intermont depression a short distance east of Columbia Falls station, bear conspicuous marks of scouring by the broad Canadian glacier, similar to but larger than those left upon the flanks of the Mission Range. Near the railway notch the terminal facets of the truncated spurs may well rise a thousand feet over the plain; but they rapidly decrease in height southward, and, beyond the last and lowest one, many other spurs trail away with long concave slopes into the intermont plain: it therefore appears that the farthest effect of the Canadian glacier along the mountain base is seen in the last spur-end facet.

The High Southern Belt. Several miles before the long morainic embankment turns west from the base of the Mission Range at the southern end of the low northern belt, the valley heads show cirque-like enlargement, as in Figures 8 and 9, and thus define the beginning of the third, or high southern belt. Unlike the other two belts, in each of which the sculpture is all of one kind—all normal sculpture in the middle belt, all glacial sculpture in the northern belt—the features of the southern belt are of two kinds, normal and glacial; but here the features of glacial sculpture are the work of separate local glaciers, each in its own valley, and the resulting cirques and troughs alternate with summits and spurs of normal erosion. The first cirque—see Figure 8—is so faintly developed that, were it seen alone, one might remain uncertain as to its nature; but there can be no doubt as to

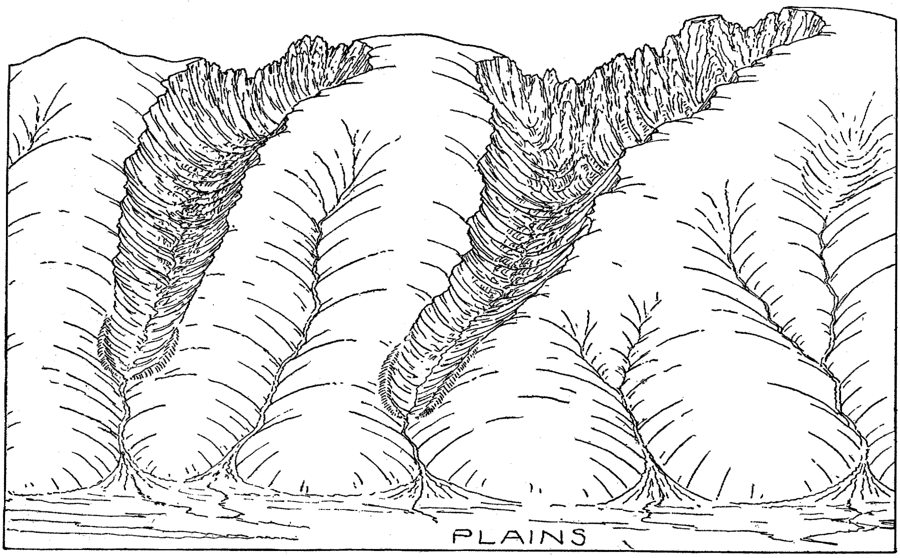

FIG. 11—Sharpened crests between opposing cirques.

its being the slight enlargement of a normal valley head by a small local glacier when it is seen as the northernmost recognizable member of a systematic series of twenty-five or more, of which the southernmost (Fig. 13) is a huge cliff-rimmed excavation in the mountain top, at least 1,000 feet deep, opening into a great rock-walled, hollow-floored trough that descends 5,000 feet to the mountain foot, where it is looped around by a beautiful though small terminal moraine. A line drawn through the lower end of all the troughs separates the middle belt from the high southern belt.

The normal features of the southern belt differ from those of the middle belt only in size and in completeness of development. They are large enough to extend through the entire height of the mountain side. Some of the spurs are subdivided by valleys of normal form that head at half or three-quarters mountain height, and therefore too low for the development

of cirques at their head; but other spurs continue undivided from mountain crest to mountain base. With increase of summit height southward, the spurs are more and more encroached upon by the intervening cirques and troughs, but the two classes of forms do not blend; they are separated by well-defined edges where the convex, waste-covered, normal form is suddenly undercut by the steep rock wall of the glacial excavation. The close association in which the two classes of forms are here seen adds force to the objections that I have elsewhere urged[5] against the empirical German phrase-words *Mittelgebirgsformen* and *Hochgebirgsformen*—that is, forms of middle-height mountains and of high mountains—as designations for features of the two classes which are here so intimately associated at the same

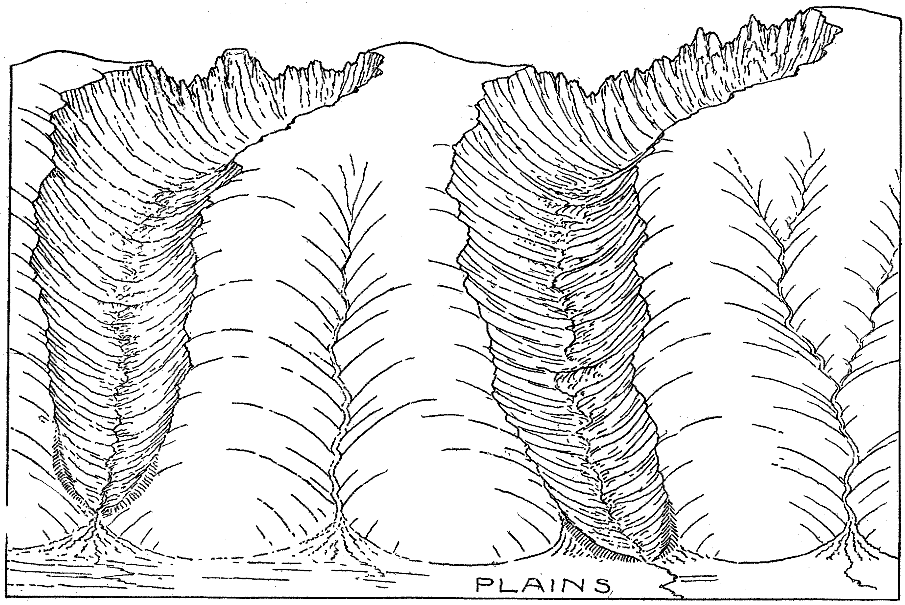

FIG. 12—The cirques are enlarged southward.

altitude; and the confidence with which the two classes are here distinguished gives renewed warrant for preferring explanatory phrases, like forms of normal and of glacial sculpture, to empirical phrases, such as round-topped and sharp-crested mountains.

Cirques and Troughs of Local Glaciers. It has surprised me on various earlier occasions to note the ease with which high-standing cirques can be made out at distances of several miles; from five to twenty miles in the Wasatch Range in Utah[6] and in the Front Range of Colorado,[7] from thirty to forty miles with a field glass in the higher ranges of Turkestan[8]; but

[5] Die erklärende Beschreibung der Landformen, Teubner, Leipzig, 1912, p. 286.

[6] The Wasatch, Canyon, and House Ranges, Utah, *Bull. Mus. Comp. Zool.*, Vol. 49, 1905, pp. 15-58; reference on p. 22.

[7] The Colorado Front Range, *Annals Assoc. Amer. Geogrs.*, Vol. 1, 1912, pp. 21-83; reference on p. 56.

[8] A Journey in Turkestan, pp. 23-119 (reference on p. 91) in R. Pumpelly's Explorations in Turkestan, *Carnegie Inst. Publ. No. 26*, Washington, 1905.

only in the Mission Range has the recognition of cirques at a distance been facilitated by their arrangement in a regularly progressive series of two dozen or more, in which larger and larger, stronger and stronger examples follow in regular procession through a stretch of forty miles. The series begins with smooth-contoured, valley-head hollows, perhaps a quarter mile in length and less in breadth, which, as above indicated, hardly deserve the name of cirques. As one's view is turned southward, the size of the hollows gradually increases, the head and side walls become steeper, with a greater exposure of base rock, as in Figure 9; farther on, as in Figure 10,

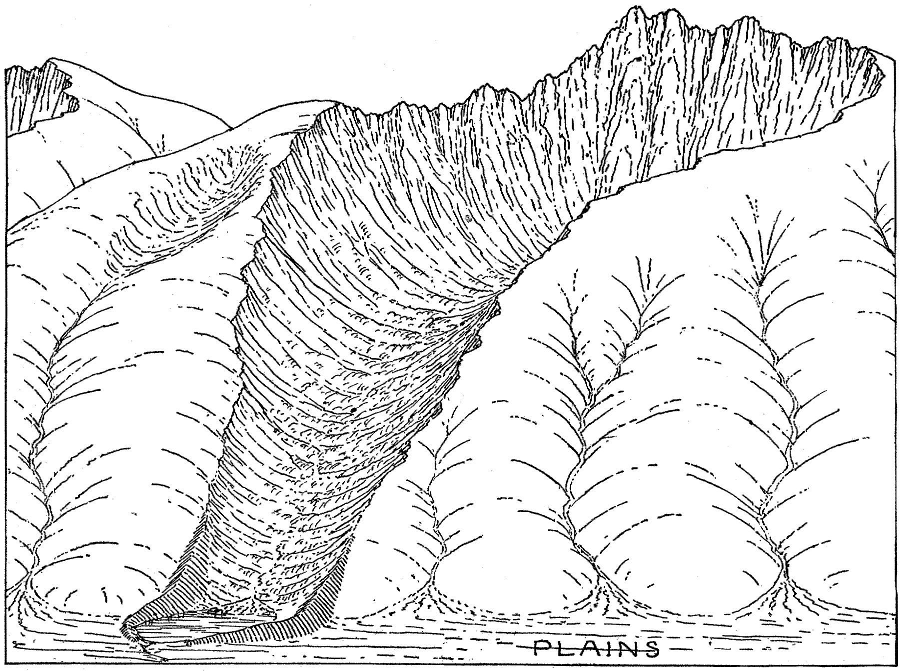

FIG. 13—An alpine crest and a piedmont lake.

the sky line of the head walls becomes notched, as if two opposing cirques had eaten through the convex crest of the mountain and locally converted it into a sharp and ragged edge, the beginning of maturity in glacial erosion of this kind; at the same time the troughs increase in length. These features characterize the parts of the range shown in Figures 15 and 17, looking across the plains south of Flathead Lake to the east and southeast. As the range increases in height a tendency is noted to the enlargement of the cirques southward, as if in exemplification of the rule that glaciers are best developed on shaded slopes[9]; and as the enlargement becomes more pronounced an extension of the maturely sharpened sky line is perceived through a greater length of mountain crest, as in Figures 11 and 12;

[9] G. K. Gilbert: Systematic Asymmetry of Crest Lines on the High Sierras of California, *Journ. of Geol.*, Vol. 12, 1904, pp. 579-588.

here the Alpine term, arête, may be well applied. With the fuller development of the cirques, the troughs gain strongly oversteepened walls and increase so greatly in length as to extend far down toward the foot of the range. The oversteepened walls have, as above noted, a sharply defined edge where they undercut the convex spurs; the bare rock, here and in the cirques exposed to free attack of the weather, is assuming minutely irregular forms and furnishing detritus to talus slopes and fans that are invading the rock floors below, but as far as I could see the change thus accomplished is small as yet. The emphatic definition of the mature cirques is strikingly unlike the vague limitation of the mature normal valley heads, and the acute

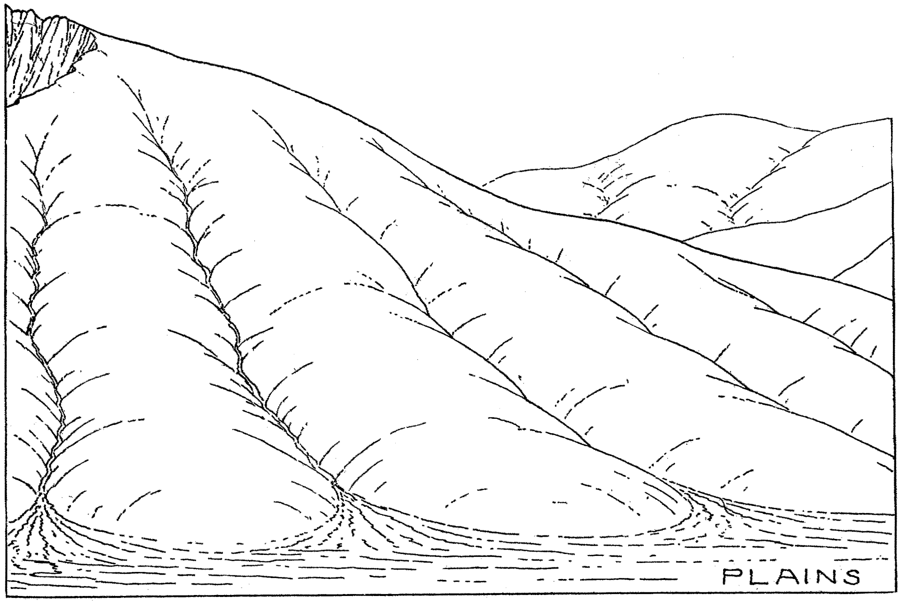

FIG. 14—Normal forms at the southern end of the range.

edge of mature arêtes, where only a narrow belt is exposed to weathering, is strikingly unlike the ample arch of the normally rounded mountain crest, where a broad belt is exposed to weathering; but both these unlikenesses are expectable in view of the fact that a mature glacier is of greatest size close to its high-level source, while a mature stream at its source is of smallest size. The broadly concave form of the troughs is strongly contrasted with the narrow concave of the normal valleys, and this contrast is intensified when one realizes that the proper homology of the large-featured glacial troughs is really found in the minute stream channels that are entrenched within the narrow valley concaves. Here one may realize the contrast between the sluggishness of a heavy glacier that nearly fills its wide and deep trough and the nimbleness of a slender stream that carries away all the ice water in a minute channel; here one may recall the comparison between mountain-

side glaciers, which in a temperate climate dwindle and disappear as they creep from snowy reservoirs down into a milder zone, with mountain-side streams, which in an arid climate wither and vanish as they run from the rainier summits down into the drier lower air.

Culmination of the Range. With continued increase in range heights, the southward enlargement of the cirques becomes so great that from a front view a large part of their interior is hidden, as in Figure 12. Finally, at the slowly attained culmination of the range close to its southern end, the largest and last cirque of the entire series is a formidable cavity, excavated half a mile or more southward of its discharging trough; and a small glacier is reported as lying concealed in the cirque head. Here the highest cirque wall, a great mass of bare rock, rises to an acutely serrate crest, forming in Mt. McDonald, 9,800 feet altitude, the loftiest peak of the range, near which the views reproduced in Figures 19, 20, and 21 were taken. The sky line of Figure 19 illustrates the simple crest of the range where it is not narrowed and notched between encroaching cirques, while the great rock face in the same view gives warrant for the steepness and ruggedness of the cirque and trough walls, as shown in the diagrammatic figures. The floor of the McDonald cirque is not in sight from the plain. The trough is a huge channel, rock-walled and rock-floored, with a fairly mature cross-section of catenary pattern. On either side the rounded spurs of normal sculpture are as typically convex as the trough is concave. The hollowed trough floor is not yet much encumbered, as far as I could determine, with talus fans; its longitudinal profile is somewhat broken by rock sills; whether rock basins occur also I could not see. The dimensions of the trough decrease as it descends the mountain side, but it is still well developed to the very foot of the range, where it is extended on the piedmont plain in the form of a terminal basin, rimmed by a well-formed terminal moraine. Farther to the south only normal forms (Fig. 14) are seen as the range rapidly declines toward the Jocko River in a long sunny slope.

The last member in the long succession of forms due to the local action of single glaciers is a fully developed example, beyond which an increase in size is possible but not an increase in completeness of detail; for between the cirque walls which rise to sharpened peaks and the trough which ends at a piedmont moraine is included the whole range of features that a single local glacier can produce. When, in addition to the features due to local glaciation in the high southern belt, are added those due to general glaciation in the low northern belt and both are viewed in their suggestive contrast with the normal features of the middle belt, the Mission Range is seen to be highly flavored with the spice that comes from variety. The concise and systematic combination of these varied features makes the range, as far as I have seen and read, unique.

FIG. 15.

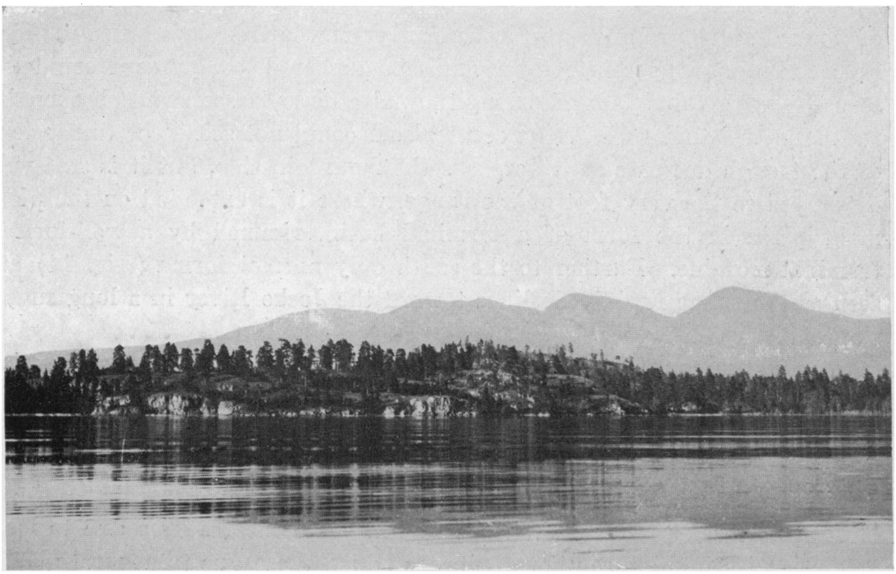

FIG. 16.

FIG. 15—Southern part of Mission Range across Mission Plains. (Photo by R. W. Stone.)—Continuous with Figure 17.

FIG. 16—A scoured island in Flathead Lake. (Photo by R. W. Stone.)

FIG. 17.

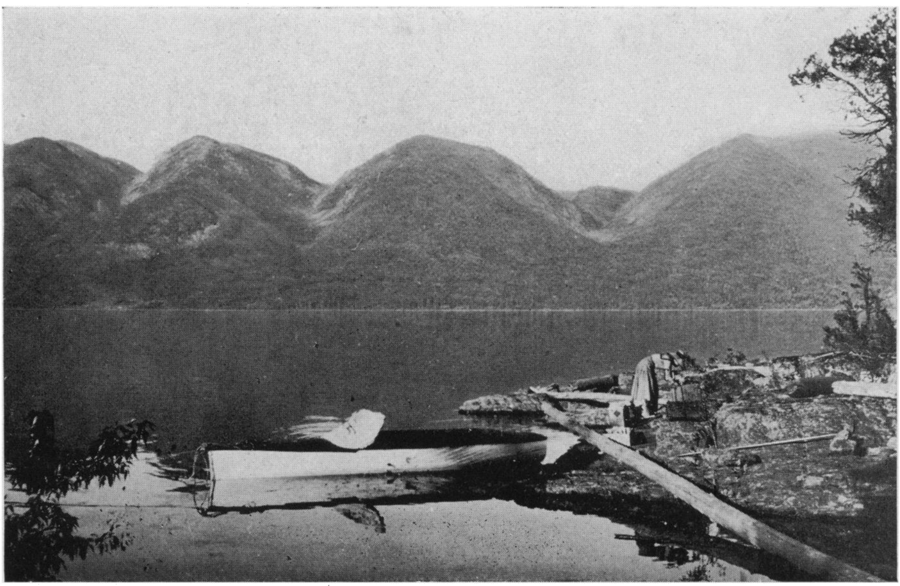

FIG. 18.

FIG. 17—Southern part of Mission Range across Mission Plains. (Photo by R. W. Stone.)—Continuous with Figure 15.

FIG. 18—Glacial troughs in Mission Range over Flathead Lake. (Photo by R. W. Stone.)

Cycles and Episodes of Glacial Erosion. Large as the McDonald cirque is, it does not represent the completion of a glacial attack upon a mountain mass; that demands a relatively rapid widening of the cirque floor and its slower lowering until the enclosing walls are consumed—the action of the weather on exposed surfaces here aiding the action of ice on covered surfaces—and the mountain mass is truncated; at the same time the thick-

Fig. 19 —Glaciers on Mission Range, southeast of Mt. McDonald. (Photo by C. D. Walcott.)

ness of the ice on the truncated surface should diminish by reason of lessening mountain height and consequently decreasing snowfall, until the thin and relatively inert glacial veneer almost or quite disappears, the glacial tongues descending from it shorten and vanish, and the truncated mass remains subject only to normal dissection by the retrogressive erosion of its flanks. Here the analogy with stream work in an arid climate may be again recalled; for just as the wearing down of a mountain in a temperate region diminishes the snowfall upon it, so when a mountain range in a desert lowland is worn down the rainfall upon its area will decrease, and eventually, when the range is reduced to low relief, its surface will be about as dry as the lowland around it and subject to further degradation rather by wind than by water action. It was, I believe, Tyndall who first fancifully suggested that deglaciation might be the result of loss of height by

glacial erosion;[10] it is now generally agreed that deglaciation was the result of climatic change. Thus two schemes of the life history of a glacier are suggested: one is the highly ideal scheme of a constant climate, during which an upraised mountain mass will, if at first high enough, be glaciated until it is worn so low that its snowfall is lessened and its glaciers disappear, as Tyndall imagined for the actual case of the Alps, and as is above outlined for a supposititious case; this involves a complete "cycle of glacial erosion",[11] in the same sense that the wearing down of an upraised mass by weather and water involves a complete cycle of normal erosion. The other scheme is the more expectable one of a variable climate, in which a mountain mass will be glaciated only as long as the snowfall is sufficient to form glaciers, as was the case with Pleistocene glaciation; glaciers were then extinguished long before their work was completed, and hence, thus limited, the "life history of a glacier" as presented by Russell[12] and the "cycle of mountain glaciation" as presented by Hobbs[13] include only a life history or cycle cut short by climatic change in its prime; that is, a mere episode of glaciation, in which only the earlier stages of a complete cycle, the earlier phases of a full life history are considered. In the Mission Range we evidently have to do only with an episode of glaciation due to climatic changes, introduced upon a mountain already well carved by normal erosion from its initial form; an episode that was closed long before the final stage of an uninterrupted cycle of glacial erosion was reached.

The Explanatory Description of Mountains. The Mission Range forms an admirable subject for close examination by a student of physical geography to whom camping and climbing are exhilarating and to whom the study of land forms is a specialty; all the better if he could go on from the forms to their climate and their inhabitants, and thus make himself a full-fledged geographer. The district is easily accessible; supply stations are abundant near the mountain base. The range is sufficiently separated from its neighbors to form a well-limited field of work. Its rocks, as far as I have learned, have neither paleontological content nor petrographical composition in such variety as to distract a would-be geographer into irrelevant geological complications. The varied physiographic features are developed with remarkable clearness; if accurately described and illustrated they might serve as standards, in terms of which other less simple ranges could be advantageously treated.

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10 Tyndall wrote: "Given the uplifted land, and we have a glacial epoch; let the ice work down the earth, every foot it sinks necessitates its own diminution; the glaciers shrink as the valleys deepen; and finally we have a state of things in which the ice has dwindled to limits which barely serve as a key to the stupendous operations of a by-gone glacial age. To account for a glacial epoch, then, we need not resort to the hard hypothesis of a change in the amount of solar emission, or of a change in the temperature of space traversed by our system. Elevations of the land, which would naturally accompany the cooling of the earth, are quite competent to account for such an epoch; and the ice itself, in the absence of any other agency, would be competent to destroy the conditions which gave it birth." (The Conformation of the Alps, *Philos. Mag.*, Vol. 24, 1862, pp. 169-173; see pp. 172-173.)

11 See reference in footnote 3, p. 294.

12 I. C. Russell: Glaciers of North America, Ginn, Boston, 1897, Chapter 10.

13 W. H. Hobbs: The Cycle of Mountain Glaciation, *Geogr. Journ.*, Vol. 35, 1910, pp. 146-163 and 268-284.

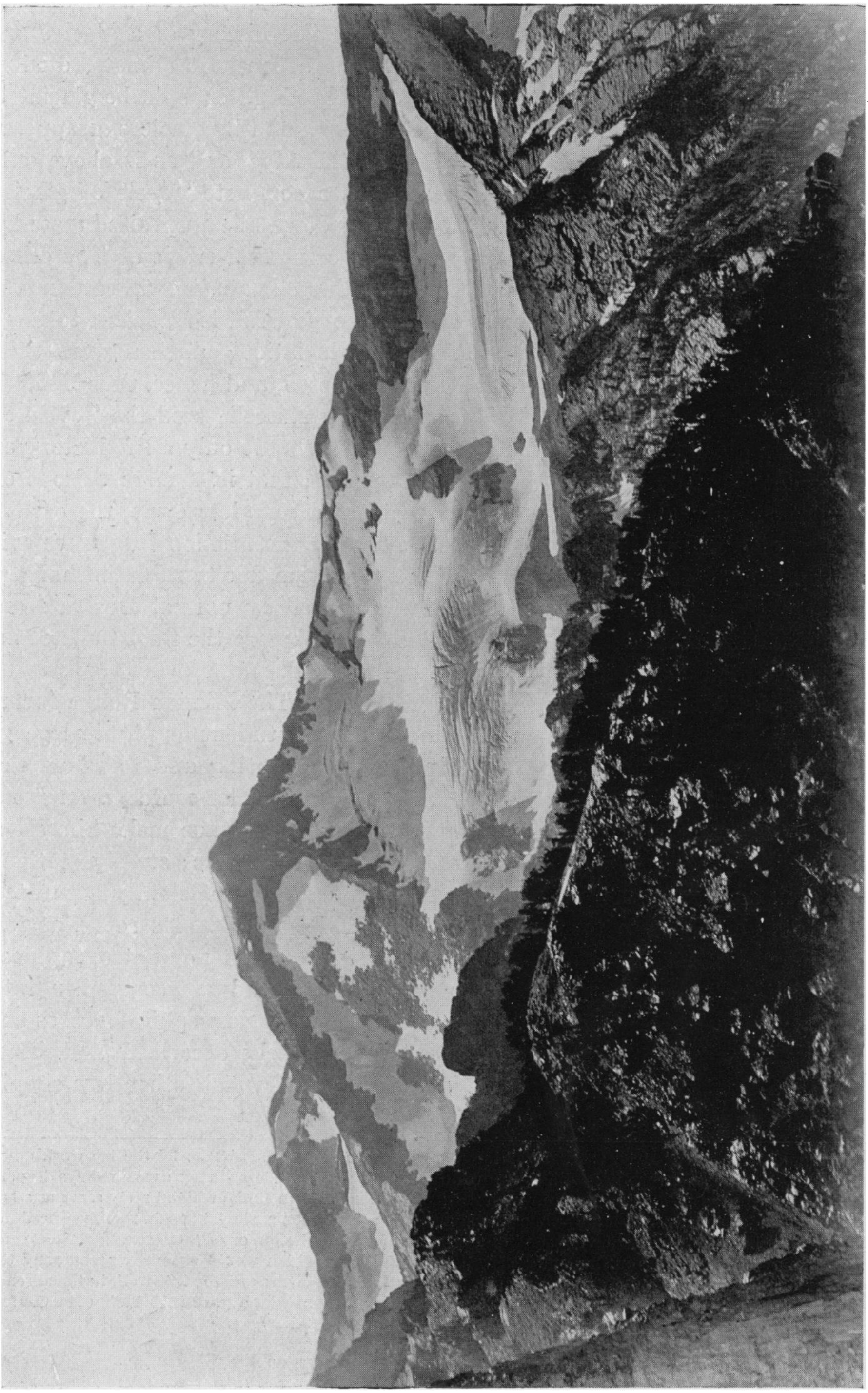

FIG 20—Mission Range in vicinity of Mt. McDonald, from head of Swan River. (Photo by C. D. Walcott.)

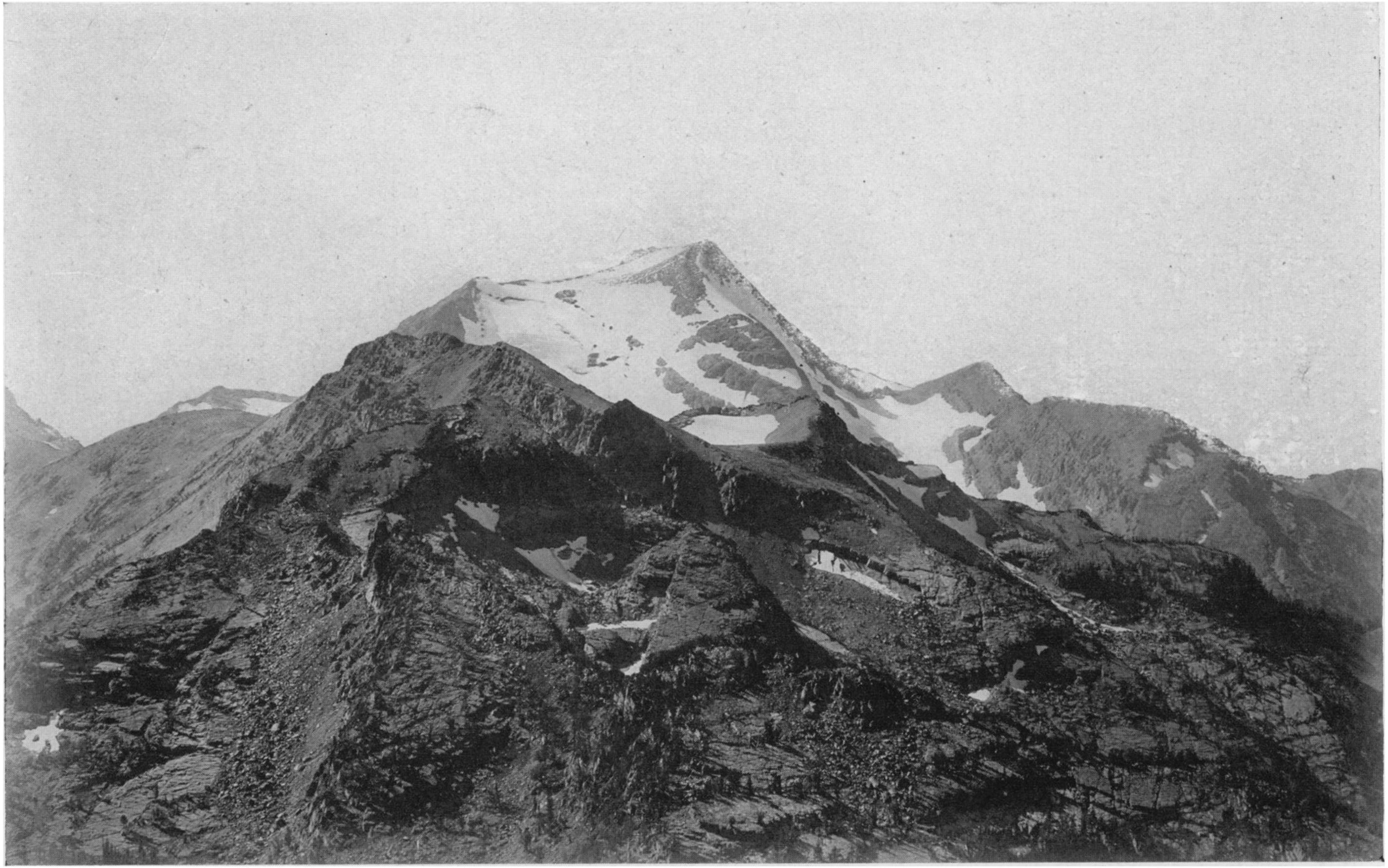

FIG. 21—Mission Range in vicinity of Mt. McDonald, from ridge on north head of Swan River. Alt. 6,900 ft. (Photo by C. D. Walcott.)

A spirit of geographical adventure has encouraged me here to set forth the results of a mere reconnaissance; first, because so little is known geographically of the individual ranges of Montana that every contribution to their further description is desirable; again, because the appearance of an incomplete account of the Mission Range may hasten the production of a more thorough study; finally and chiefly, because incomplete as this account is, it has a value in showing that a systematic method of treating land forms is sometimes applicable in rapid work, where conservative geographers of the empirical school think it is inapplicable, their idea being that explanatory description must demand long and intensive study, and therefore cannot be based on brief inspection.